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UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
R. R. SAYERS, ACTING DIRECTOR

INFORMATION CIRCULAR

MORE JOBS FOR MINERALS

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BY

PAUL M. TYLER

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

MORE JOBS FOR MINERALS[1]

By Paul M. Tyler[2]

One of the best present-day yardsticks of the material welfare of a nation is its consumption of minerals. The United States, with only 7 percent of the world population, consumes 45 percent of the world wealth, pays the highest real wages, has the shortest working hours, and numbers the largest percentages of home owners among its population, and at the same time its per-capita consumption of minerals is far greater than that of any other nation. In 1937, British India, with roughly twice the population of the United States, used less than 2 percent as much lead, 4 percent as much zinc, and 13 percent as much copper; even in Europe, which has three times our population and where war preparations have greatly expanded the normal needs of peaceful industries, the aggregate consumption of metals and industrial minerals other than lignite is less than the total for the United States alone.

The march of civilization passed from the Stone Age to the Bronze Age before the dawn of history. It may be questioned whether man or monkey first threw stones at an enemy, but only man could have fashioned rough stones into weapons. Eoliths rudely shaped by apelike men are believed by archaeologists to have antedated by hundreds of thousands of years the existence of our own human ancestors. The primitive people that followed the retreating Ice Cap northward in early Quaternary period - at least a million years ago - were fairly adept in the shaping of flints and even used a little copper. The Bronze Age, so-called, superseded the Stone Age when, around 8,000 B. C., the news spread that chunks of natural copper could be pounded into better weapons or cutting implements than ever could be made by chipping stones. The Bronze Age gave place to the Iron Age about 1,000 B. C., and though students of modern history may speak of the Coal Age, the Petroleum Age, the Automobile Age, and so on, these ages have all been crowded into a brief century and a half. The truth is that we still are in the Iron Age, unless perhaps we choose to call it the Age of Many Metals.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7118."
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Growing Use of Minerals

Primitive man had few utensils and no machines worth mentioning, but the things that made history, that helped him most in his struggle for existence and toward a more abundant life, were things of metal - knives, axes and spearheads. Whether in plowshare or sword, metal plays a leading role. The earliest metal known is believed to have been gold, although copper was known very early in Egypt and iron was used freely by the Hittites and related peoples during the period of the 18th dynasty. Silver, lead, and iron were employed to some extent in very ancient times but seem to have been quite scarce. Brass was known in Palestine perhaps as early as 1400 B. C., though it did not appear in Europe until the Roman period. However, zinc was not produced separately from its copper alloy much before 1800 A. D. Early peoples used bronze, but how they got the necessary tin is still in doubt. Natural pitch or bitumen was used to embalm Egyptian mummies, and the first reference to an oil well was written by Herodotus about 450 B. C., but most of the development of the petroleum industry has occurred within the memory of those who are now only middle aged.

In Periclean Greece, a quarter million free men were served by at least an equal number of slaves, but the smallest American village is better powered than was the Athenian economic machine. The ratio of handpower to mechanical labor varies from country to country, but in the United States the energy derived from coal, petroleum, and waterfalls is greater than would be available if each of us had 40 or more slaves to do his heavy work. On the basis of our 1,231 million installed horsepower in 1935, some of which was idle at least part of the time, every man, woman, and child in the United States has 90 slaves either working or ready to work. Properly applied, only 2 pounds of coal, worth about 1/5 cent, will do as much work as can a man in a day.

Unless our historians are greatly deceived, the standard of living of the average man advanced amazingly little from the earliest times until about the beginning of the 19th century. Some years ago, slide-rule calculators of the Technocrats declared that the average American consumed 75 times as much goods and services as did his ancestor in 1800, and that two-thirds of this increase had taken place after 1900. This estimate, too, was on an energy basis. A philosopher may discern a better criterion of our general well-being, and others may doubt whether the volume of goods and services produced affords the best measure of human happiness or spiritual values, but there are no better figures to indicate man's progress in physical comfort and well-being. Figures of the Machinery and Allied Products Institute show the United States leading in mechanical horsepower used: The average horsepower per worker in the United States is 4.86; in Germany, our nearest competitor in this respect, it is 2.61; in Great Britain, 2.56; in Canada, 2.17; in Italy, 2.14; and in France, 1.78.

It is no mere coincidence that the world employment of minerals has paralleled its progress in other material ways. The total consumption of metals and minerals during all the centuries before 1800 was quite insignificant compared with modern needs (probably less than it is now in a single year), and the total output of the world's mines, quarries, and wells before 1900 failed to equal the quantity produced during the last 30 years. As recently as 1820, this country produced but 5 pounds of pig iron per capita, whereas in 1920 it needed 597 pounds, 119 times as much. Steel-consumption figures are even more striking, rising from less than half a pound per capita in 1790 to 130 pounds in 1850, 1 1/2 tons in 1901, and 9 1/2 tons in 1939. According to Tryon and Mann 3/:

> In the hundred years from the close of the Napoleonic Wars to the outbreak of the World War, the white population of the world increased 3-fold, but the output of tin increased 26-fold, of copper, 63-fold, of the mineral fuels 75-fold, and of pig iron over 100-fold. Lead and zinc showed corresponding increases.

Prof. G. A. Roush, editor of Mineral Industry (1937 edition), has calculated world index numbers for mineral production after 1913. Contrary to popular impression, the World War - or, as pessimists are beginning to call it, World War I - did not increase the supplies of most minerals. Not until after 1922 was the upward trend confirmed. By 1929 Professor Roush's index of total output of leading minerals jumped to 136, compared with 78 in 1914, an increase of almost 75 percent. After dropping to 88 in 1932, it recovered rapidly, and in 1937 topped its previous record.

Increasing Variety of Raw Materials

More striking almost than the increase in volume is the increase in variety of industrial raw materials. Until Revolutionary days, foods, fibers, and wood were the chief materials of industry, and not more than half a dozen metals were employed to any extent. As recently as the beginning of the present century, the list of useful metals comprised iron, copper, lead, and zinc, supplemented by very small quantities of tin, antimony, gold, silver, platinum, and a few minor metals. Mercury and bismuth were used medicinally and to a meager extent in the arts, but nickel and cobalt, in common with manganese and silicon were employed but little outside of the steel industry. The chemical industries and other large industrial consumers of mineral raw materials were in their infancy, and even architects and builders were satisfied with relatively few kinds of structural materials. Coal or peat, clay for the potter and bricklayer, a little sand for glassmakers, salt, whetstones and millstones, and perhaps a little mica were virtually the only nonmetallic minerals needed, apart from building stone.

The main achievement of the 19th century was the rise of heavy industries and factory production. As steam relieved human muscles from the most arduous drudgery, the Industrial Revolution sought first to provide more abundantly the primitive wants of the common people. There was little demand for materials other than those already at hand. Men and women in the

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3/ Tryon, F. G., and Mann, L., Mineral Resources of Future Populations: Population Problems in the United States and Canada (edited by Louis I. Dublin). Houghton Mifflin, Boston, 1926, p. 114.

lower income groups had to be furnished with adequate food and clothing before they could be made to buy automobiles, radios, and more complicated things that had not yet been invented. Diversity in manufacturing industrie with its accompanying demand for a larger and larger assortment of raw materials was a later development.

No limits can be set upon the volume of total goods and services that can be made and sold, for human wants are insatiable. Beyond certain flexib limits, however, an increased volume of sales can be attained only by increasing the variety of goods offered. A hungry man may want food above all else, but once his hunger is satisfied he begins to want other things more. The law of diminishing returns is a fundamental principle of economic and explains the eagerness of automobile manufacturers, for example, to build radios, refrigerators, air-conditioning equipment, and other products to sell to customers who already have automobiles. Some families have two automobiles, but few have more than three or four, not so much because they can't afford to buy them as because there comes a time when another car adds nothing to the convenience of their living.

To meet the increasing demands of industry, new metals emerged from the laboratories, one by one, and found jobs. During the first 3 decades of the present century, the number of metals in active use more than doubled, and research proceeds today at a still quicker pace to expand our knowledge, and, if possible, our utilization of all the 92 elements that chemists recognize as comprising the essential building blocks of matter. The mineral fertilizers were a development of the nineteenth century, and the expansion of the portland-cement industry combined with the demand for better structures of all kinds has created new products even in the humble field of sand and gravel. Many of us can still remember when road building, for example, was done largely by farmers, who worked out their taxes by their own manual labor and an occasional team of horses, using only local materials from roadside pits. The materials used today for road construction are as vastly different in quality and variety as are the modern highways themselves. A year's output of sand and gravel in the United States bulks larger than 30 of the great Egyptian pyramids.

Anonymous Services

Many modern uses of metals are invisible, and in many important uses the services rendered by minerals are unrecognized except by those who actually make the products or supply the materials. Even those who know that the slender filament of an incandescent lamp is tungsten may never have stopped to think that were it made of a less efficient material, which formerly was employed for the same purpose, four times as much current would be required for lighting. In other words, in this instance, a few pounds of the right metal takes the place of tons of costly apparatus for the generation and transmission of unnecessary electricity, releasing corresponding quantities of fuel or power for other industrial uses. Still more economical are the new fluorescent lamps which likewise owe their high luminous efficiency to rather minute quantities of metal salts. Relatively few persons realize that the life of a tungsten filament is prolonged by "flashin the bulb with a pinch of zirconium or other oxygen-hungry metal, and by filling the bulb with an inert gas captured from the atmosphere and concentrated, or that traces of thorium or other rare metal may be used to make the tungsten ductile enough to be drawn into a filament. A tenth of 1 percent of copper delays corrosion of steel; a similar amount of molybdenum or vanadium makes it stronger and tougher. A few hundredths of 1 percent of tellurium harden and toughen lead to an amazing degree. Five parts per thousand of tetra-ethyl lead give gasoline antiknock properties, and 15 parts per million of silver are used in the purification of water and alcohol.

Popular advertising has apprised most people of the fact that steel is made stainless by combining it with chromium, but the man on the street may not know that streamlined designs requiring welding could not be achieved if the stainless properties of the alloy were not stabilized and protected by minute additions of columbium or other rare metal. The less common metals are a far larger factor in our modern life and industry than is generally appreciated. Because their main functions are to enhance the properties of other materials, many alloying metals seem destined forever to act behind the scenes and may never aspire to more than insignificant rank in dollar value of products. Mica is one of the most modest of minerals and is less well known now than it was in the days when members of a slightly older generation gathered around the hot stove and confirmed their comfort by watching the fire glow through windows of this transparent mineral. Mica now has a hundred new uses in the electrical industries. Suddenly deprived of mica, our cities would be dark, factory motors would cease to turn, automobiles and trucks would stop short, airplanes would be grounded, and communication by telephone, telegraph, or wireless would be impossible. Without laboring this point further, it might be mentioned that the nation spends only a few hundred thousand dollars a year for the mica needed for strategically important industries whose products and services are valued at many billions of dollars annually.

The average man, says one of the large steel companies, carries on his person 110 pieces of steel; the average woman, 89, lipstick holders alone consuming 327 tons a year. A 1938 model radio owes part of its tonal reproductions to a tiny coil of aluminum only 0.002 inch thick and weighing about 160 milligrams. It has been shown that every person in the United States uses about 125 pounds of sulfuric acid a year. This is fully five times his consumption of soap and 16 times his consumption of table salt, yet how many know where this acid is used?

Most of us read books and write letters, but how often do we stop to think that high-grade paper may contain as much as 20 percent clay as filler and coating and that sulfur, chlorine, lime, sodium compounds, and other materials of mineral origin are as important as vegetable fibers in paper making! Recently, mineral fiber (low-grade asbestos) has been used to cheapen cardboard, and mineral fillers are a factor in the manufacture of linoleum, textiles, plastics, paints, and countless other products that we ordinarily do not associate with the mineral industry at all.

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In the fiscal year 1939, the Government Printing Office alone, in maintaining in working condition its 5,000 tons of type metal, had to buy 6-1/4 tons of tin, 2-1/2 tons of lead-antimony alloy, 75 tons of lead, and 60 tons of universal alloy. It also acquired 275 tons of metals on an exchange basis, trading in as part payment 190 tons of scrap. Powdered metals and minerals are used in inks, gold and other metal leaf for stamping titles of book covers, zinc plates and other metal products in electro typing, and acid is used for etching purposes. Compounds of heavy metals are used not only in printing but in the manufacture of the paper itself. So-called onion-skin or Bible papers owe their opacity to zinc sulfide or titanium pigments.

In February 1939 was celebrated the 100th anniversary of Goodyear's invention of the method for vulcanizing rubber. The rubber industry is a large consumer of minerals. The process of vulcanizing is essentially one of combining sulfur with crude rubber, and modern rubber contains a great variety of minerals not merely as fillers or cheapening additions but as compounding ingredients that increase strength and durability. Rubber heels for footwear may contain 40 percent or more china clay, by weight, in addition to other minerals. Talc, pyrophyllite, or powdered mica may be used to prevent rubber sticking to the molds; and, of course, the molds themselves and the mixing machinery are mostly made of metals, and the steam heat usually is generated by mineral fuels. Synthetic rubbe is made from limestone, coke, and salt.

We use minerals every time we wash our hands. Soap has been the customary cleanser for centuries; and although our great-grandmothers used to obtain the mineral salts from wood ashes, commercial soap makers derive the necessary chemicals from raw materials taken from mines or salt wells. American Indians and many of the early settlers of the Middle West used bentonitic clay for washing when soap was a luxury. Now soap itself is not good enough for some washing jobs, because fatty acids form insoluble compounds with lime. Accordingly, many new all-mineral cleansers and purifiers are now employed, among the latest being complex phosphates, sodium silicates, and metallic fluorides.

Minerals and their products are employed in nearly all the food industries and find a place not only in the saltcellar and in salted fish and meats, but in phosphate baking powders, in baking soda (bicarbonate), and in a variety of preservatives. Bottle washing and general cleansing and disinfection are accomplished with alkalies and chlorine, joint products of common salt. Mineral zeolites are used in water softening, and other chemicals are employed in safeguarding municipal water supplies. Ice and even water are minerals, though miners are not needed to harvest them. Dry ice, however, is commonly a product of the mining industry, whether the carbon dioxide of which it is composed is produced by burning coal, caught as a byproduct of lime or cement plants, or captured directly at the casinghead of a natural-gas well. Many of our fruits have to be cleaned and various food products have to be clarified with mineral agents. Thus diatomite is used to purify sugar solutions, while lime, and sometimes strontium compounds, are even more essential to sugar-refining processes. The well-known maraschino cherry is first deflavored by a sulfur compound and stored in brine before being artificially flavored and colored - often with coal-tar products. Ripe olives are inedible until they are soaked in brine and treated in one alkali bath after another. Calcium chloride is a common enough chemical, a waste product at some plants and widely used nowadays for laying dust on highways and for dustproofing coal and coke. Just a tiny bit of it, however, often no more than 30 grains per 100 pounds, is used in canned tomatoes to keep the fruit firm and fresh-looking. More obvious is the fact that the miner furnishes the materials for knives and forks, plates and cups, pots and pans, and the stove and fuel for cooking; the steel and tin for cans; the sand and other raw materials for glass containers; and the metals and other materials for transportation equipment, as well as coal or gasoline for motive power for bringing food from farm to factory, home, or hotel.

Food from Mines

We are reminded repeatedly that the farmer feeds the Nation. But who feeds the farmer? Breadstuffs, fruits, vegetables, corn, and cotton - in fact, almost all foods and fibers, even the flowers that bloom in the spring-depend more and more on the miner.

A parlor guessing game - more popular in the 1890's than in these swifter moving times - often begins with an attempt to classify things in one of three kingdoms - animal, vegetable, or mineral. Everyone knows that the animal kingdom feeds upon the vegetable kingdom, but it is equally true that the vegetable kingdom in turn depends upon the mineral kingdom. A few examples have been given of the use of minerals in preserving foods and every wide-awake farmer knows of the need for fertilizers of mineral origin to nourish crops and to condition the soil. April showers bring May flowers - and oats and apinach, too - only when the soil can feed as well as support the plants. Air, sunshine, and moisture are only part of the story. Minerals enter into our own food and into the feeding of stock in ways more subtle than merely adding fertilizer to get a crop or even combating insect enemies with death-dealing insecticides.

The human body contains a dozen or more mineral elements, all of which could be bought separately as chemical products for about 30 cents. Yet, lack of a tiny trace of even one of them can completely alter the state of health. Important elements in human architecture and bodily well-being are sodium, phosphorus, calcium, magnesium, chlorine, fluorine, iodine, sulfur, iron, manganese, copper, zinc, and cobalt. Oxygen, carbon, and water are omitted because these are obtainable from the air as well as from minerals in the earth.

Rickets has been attributed to lack of vitamin D, but deficiency of phosphorus and calcium is equally serious. All three are required for good bones. Doctors tell us that minor elements are about equally important, though we don't need much of them. Take copper. If we could eat it slowly and digest it, an ordinary 1-cent piece would give each of us enough copper to last us 20 months. Yet the lack of even this seemingly trivial quantity may cause pernicious anemia. Iodine is used quite generally in certain regions as an addition to local water supplies or as iodized table salt to combat goiter. Small quantities of manganese are essential to motherhood and help in the growth of children. When deprived of enough manganese in their diet, rat mothers in a laboratory have turned against their offspring. "Bush sickness" in cattle and sheep has been attributed to a shortage of cobalt. Other elements, such as fluorine or selenium, though seemingly needful in small amounts, cause serious difficulties when taken in large quantities.

Only within the last decade or so have we even suspected the importance of some of these minor elements in diet and nutrition, but animals know it instinctively. Stock will cluster on a well-fertilized spot in a pasture, preferring grass that grows on fertile soil and so contains needful elements. Plants as well as animals not only grow faster when well-nourished but can better resist disease and insect pests.

More than half of the 90-odd elements have been found in plants and in an almost infinite variety of combinations. All of these elements may not be really essential, but at least 22 of them definitely are. Many are naturally present and abundant in most soils, while others are supplied more or less involuntarily in commercial fertilizers, either as impurities or as chemically bonded carriers of other desired elements. Nevertheless, hard-worked soils may need replenishment of other elements besides the big three - nitrogen, phosphates, and potash - and a great deal of attention is given nowadays to what may be described as the proper seasoning of plant foods to round out the diet of particular plants in particular localities. These studies are all the more necessary because of the trend to use more concentrated fertilizers as a means of saving freight.

World farmers spend, roughly, a billion dollars a year for commercial fertilizers; American farmers alone normally buy 8 million tons, at a cost of$200,000,000.

In some countries, notably in the Netherlands, much more fertilizer is used per acre than in the United States. American farmers ought to use more, but it seems doubtful that they will in the near future. In fact, the industry has done well to overcome the handicap of a reduced cotton acreage, diminishing exports of grain, and steady migration from worn-out lands in the South to newly opened irrigation projects and other lands that will need no fertilizer for years to come.

The principal mine products used in feeding the nation are phosphate rock and potash salts. Neither can be eaten directly, and phosphates usually are given a chemical processing before they can be assimilated even by plants. For nitrogen, the third main essential, we depended before the World War almost wholly on nitrate or saltpeter mined in Chile, but now we get much of it from the atmosphere. Leguminous plants and black locust trees reach up into the air and capture nitrogen, which they store in their roots, but a long time elapsed before chemists became clever enough to accomplish this economically on a large scale.

Another important source of nitrogen is coal, which yields ammonia liquor as a byproduct when converted into coke or made into city gas. Sulfur is almost as important as the big three. It is used chiefly as sulfuric acid to make the phosphate in phosphate rock soluble or "available" to plants; but it is the acid that fixes the ammonia in ammonium sulfate, and it enters into other fertilizer reactions. The lime in phosphate rock remains in superphosphate in combination with sulfur from the acid, but quantities of lime are added for its own sake directly as burned lime or as powdered limestone. Dolomitic or high-magnesium lime is used increasingly to provide magnesium as well as calcium, although growers of tobacco, potatoes and citrus fruit in particular, also buy kieserite, epsom salts, and other magnesium compounds to tone their crops. Calcium sulfate, in the form of gypsum or land plaster, is used mainly by peanut growers in Virginia, but probably would be employed in much greater quantities were not its elements to the extent of roughly half the weight, already present in ordinary superphosphate. Manganese is being added more and more to many brands of fertilizers, and boron is another minor ingredient that is receiving increasing attention. The range of mineral products used in fertilizers is being extended.

Nearly as important to the farmer as fertilizers today are insecticides and fungicides. These products are almost entirely chemicals processed from minerals won by the miner. Topping the list is arsenic of which a few thousand tons a year was needed only a couple of decades ago. Today, world metallurgists collect as much as 60,000 tons of it annually, and almost half of this total is used by American farmers alone. Important arsenical insecticides are calcium arsenate, bordeaux mixture, paris green, and other compounds in which the arsenic is accompanied by lime, lead, or copper. The sulfate of copper is used in certain sprays, and the long list of plant-protective minerals includes sulfur, cryolite and fluorspar, zinc, mercury, barium, lime, and products made from petroleum and coal. Talc, clay, and other carriers for insecticides and fungicides likewise are of mineral origin.

Common salt has value as plant food, though it is used also as weed killer - for destroying as well as upbuilding. Among its various derivatives used for destructive purposes are chlorine gas and various chlorates. Directly or indirectly, however, all industries and all persons depend on salt for their very existence. No living thing could live long without it.

The miner serves the farmer by furnishing the metals that are used in his automobile, tractor, machinery, tools, pots, pans, and wire fences. The cement for concrete floors and silos, bricks and mortar in other structures, plaster on the walls, and the pigments in paint all come from the miner. These indirect contributions are quite as important to the livelihood and comfort of the one-third of our population that still lives on farms as they are to the rest of the people of the Nation, who buy their food from the farmer.

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Place of Minerals in Modern Industry

Agriculture and mining are the basic industries. Every material thing that men need comes from the earth - everything we eat, drink, wear, or use, and all our dwellings, conveyances, tools, necessities, or luxuries. It has been pointed out already that agriculture depends in part on mining. Manufacturing industries depend even more than agriculture on mineral raw materials. It is easy to see that metal manufactures trace their ancestry back to mines, and that stone, brick, cement, plaster, roofing, and many other building materials are of mineral origin. In good times, building is a 6-billion-dollar industry. From raw materials costing only half a billion dollars a year, of which $350,000,000 worth comes from mines and $150,000,000 worth from farms and forests, the chemical industry produces industrial chemicals that, in turn, constitute the raw materials used in 60 billion dollars' worth of manufactured goods. In the whole chemical field we find 6,500 chemical plants in the United States employing over 250,000 workers and paying $350,000,000 annually.

The effect of mining in populating and building pioneer communities can scarcely be exaggerated, and even in the more settled regions the effect of mine pay rolls is far-reaching. A study sponsored by the Salt Lake Chamber of Commerce indicates that in the State of Utah more than 10 men were employed indirectly to serve one miner and his family, and that four more were needed on the farms to feed those who depended on his earnings.

A ton of steel is made from about $5 worth of iron ore plus about $2 worth of fuel and flux; but before it leaves the mill as raw material for manufacturing industries, it has a value of $30 to $40. Further fabricated into an automobile, its value rises to $500 or more. Fashioned into a watch spring, a single ton of steel might be worth 2 billion dollars. Similarly, a pound of aluminum worth 20 cents in the form of an ingot may be worth $3,000,000 when drawn out into a slender wire; aluminum wires only one-fourth as thick as a human hair are used in galvanometers.

Cigarette papers, shoe polish, flavoring extracts, perfumes, underwear, drugs, photographs, soap, explosives, dyes, ships, and sometimes sealing wax either contain or are processed with mineral products.

In view of the dominant place of minerals in modern life and the many industries that have been built upon mineral raw materials, it may be disappointing to find that even in the United States, the leading mining country in the world, the value of the annual output of mineral products reported by the Bureau of Mines in the Department of the Interior has exceeded 6 billion dollars only twice in our history. This seems small indeed when compared with a gross national income of 70 to 80 billion dollars from all goods and services produced. For metals alone, the maximum was only $1,475,990,000 at the 1929 peak. Scarcely 2 percent of all gainfully employed persons are directly on the mining industry pay rolls; not more than 800,000 actually work in and around mines, and only 100,000 in metal mining , coal mines employing by far the largest group of underground workers.

Nevertheless, as John W. Finch, former director of the Bureau of Mines has pointed out, between 60 and 70 percent of the entire wealth of the United States (conservatively valued in 1932 at more than 163 billion dollars) originated in the mineral industries. This percentage is larger than the contribution to current production, because most of the minerals won from nature do not vanish into thin air like the strains of an orchestral symphony. Except for the fuels, which, like food, are promptly destroyed by use, our metals and industrial minerals are transformed mainly into buildings, highways, bridges, railroads, power and telephone lines, water works, sewerage systems, and other durable facilities that render useful service year after year, not to forget the current and accumulated effect of our gold and silver production on our financial structure. It has been estimated that our aggregate national savings average about 4 percent of our annual income, and that they are mostly invested in durable goods of mineral origin.

More Jobs for Minerals

It is impossible in a relatively short paper to do more than suggest the manifold jobs that minerals hold. An effort has been made, however, to indicate in a general way how important they are in our daily life, how they contribute to our welfare and well-being, how they make jobs for many workers, and how they form the foundation of most of our durable wealth. Dean Edward H. Kraus, of the University of Michigan, in a radio address in June, 1939, listed the outstanding contributions to our civilization during the past 50 years that explain the enormous use of minerals in our present-day economy. These contributions include, first, the great number of revolutionary scientific discoveries; second, the widespread opportunities for education; third, the emphasis on research in our colleges and universities and in industry; and fourth, the general mechanization of our daily life, an immediate result of the factors just mentioned.

It is pertinent to inquire whether we shall keep on needing more and more kinds of minerals in ever-increasing quantities. This is not merely an academic question, and it concerns not only the mineral industries but looms large in national and international politics. As James W. Furness of the Bureau of Mines, pointed out in his University of Maryland address in 1939, minerals are tremendously important from a strategic point of view and afford one of the prime motives for wars such as now rage in Europe and Asia. The "have-not" nations want to be assured of supplies of mineral raw materials on terms satisfactory to them.

In the United States, especially, it has been customary always to expect continued growth. Little businesses expect to grow big, and big businesses expect to grow bigger. If current sales are not running ahead of last year's we blame the management. A quarter century ago there was no limit to optimism. Our cities were growing rapidly, and almost every industry was expanding. Since 1914, we suffered war, readjustment, inflation, depression, recovery, and in late 1937 recession. Now we are a little more hopeful again, but our confidence in unlimited growth has been shaken. We are told that our population will become static or begin to decline, perhaps, before another quarter century shall elapse. Exports, we have learned, do not afford a stable basis for expanding sales and never did afford a market for more than 10 percent of most products. Economists tell us that the growth curves of all industries are S-shaped. After rising abruptly they eventually flatten off and may even decline. Faithfully following this S-shaped pattern many of our mineral industries show a turning point in 1914, and some of them seem to have stopped growing altogether.

The picture is too confused at the moment to permit anyone to state definitely which industries are going downhill and which are still in process of vigorous growth; moreover, the trends in the United States alone are somewhat more mature than those abroad, because certain more backward countries are beginning to catch up with us industrially. The world coal output, for example, has virtually ceased to grow, but this is due largely to declines in the United States and Great Britain, which are partly offset by increases in Germany and the Soviet Union. Petroleum production keeps on rising steadily, with the domestic output lagging only a little behind the advance in the world total. In respect to pig iron, the trend is not so clear, but increases abroad seem to have offset any decline that may have occurred in this country, and this is certainly true of the leading nonferrous metals - copper, lead, and zinc. The light metals, aluminum and magnesium, are being produced in continually increasing quantities, as are also most of the minor or rather rare metals. Even tin production, after threatening to continue sidewise or perhaps decline, recently has resumed its rising trend. Among nonmetallic minerals there are various cross-currents, and the reluctance of building in the United States even to approach again its 1928 peak makes for some uncertainty. Nevertheless, the aggregate demand for minerals all over the world is definitely increasing, though probably not quite so rapidly as it was during the first two decades of the present century or before 1929.

Many believe firmly in increased consumption of goods. The United States may have lost its geographic frontiers but since its standard of living can rise indefinitely there is no limit to what we can make and sell, provided we can maintain a reasonably workable basis for exchange of goods and avoid excessive unemployment. It does not follow, however, that the demand for minerals in the United States or in the world at large will keep on growing forever. For the moment, let us ignore substitution and merely pose the question as to whether we are not reaching gradually the stage where our appetite for minerals will be more nearly satisfied and we shall want other things more. The world of civilization has developed many turning points. Primitive peoples progressed from a pastoral to an agricultural economy. There was a time when the building of pyramids consumed most of the surplus energies of the then civilized world. Later came the development of the Jewish religion in Palestine and the spread of commerce by the Phoenician merchants. The flower of Greek civilization was its sculpture, architecture, and perhaps the beginning of philosophy. The Romans developed road building, public works, and military strategy and codified the laws that have helped to define the relations between individuals and the State. The Renaissance in Europe was a period of change; it was followed by the Reformation and preceded by other religious movements of profound significance, of which the Crusades were but one example. A period of colonization was ushered in by the discovery of America. Three centuries later the widespread demand for individual liberty manifested by the American and French Revolutions almost obscured at the time the beginning of the Industrial Revolution. Are we still in the era that began after James Watt first contrived, in 1775, to harness steam? It would seem so, but it is not impossible that a new era is in the making. In any event, as previously stated, the economic changes of the present era have come in a series of waves. In terms of minerals, the need for coal to burn under boilers came first, next the demand for metals to make machines, and later the demand for more diverse materials for ever more complex products and services. The outposts of science are spread so wide that it is difficult now to determine which frontiers are being pushed ahead fastest. Transportation and communications seem to have progressed more than housing. The swiftest advance of all, however, seems to be in the synthesis of chemical compounds. The modern chemist is an architect and builder. He builds molecules almost as a mason builds a wall, and for his atomic building blocks he is beginning to use the materials closest to hand. In a few years he may even be able to trim his atoms to suit his needs.

Statisticians, like surveyors, need a fairly long backsight before laying out a future course, and in economic affairs the visibility is seldom perfect. Moreover, until the technique of statistical forecasting is improved further it is hazardous to prophesy what lies ahead for minerals, which industries are dying out, or which are destined to grow even faster. Most of the new services offered today - such as rapid transport, radio, television, air conditioning - demand minerals, but generally not in great bulk. Already we are using more fine steel and less common pig iron, more refined products in every field. An investigation of the manufacture of railroad spikes uncovered that a modern railroad spike is a product designed with great care, made from carefully controlled material, fabricated with precision, and a product far superior to the railroad spike of a generation ago. Even aluminum leg bands for carrier pigeons are scientifically designed and manufactured. Our common metals of today are purer than those commercially acceptable during or before the World War. It is debatable whether a new civilization will arise that needs fewer minerals, but it is reasonable to suppose that the minerals that will be produced in steadily increasing quantities will be those that are cheap. Included as cheap are not only those that cost little per pound, but even those that are peculiarly efficient, of which a little goes a long way.

As chemists grow more expert in the rearrangement of atoms, they have a wider choice of raw materials. The natural state of combination of the elements in nature will become less important. Under these circumstances, sulfur, for example, will be taken from the nearest source, whether it be brimstone, pyrite, gypsum, or smelter smoke. Magnesium is one of the most abundant elements; nevertheless, magnesia refractories were made until recently from Austrian magnesite almost exclusively. Later, other magnesite deposits were utilized, and about 2 years ago a California company began making a synthetic product from sea water. Nowadays, when we want magnesium or any of its compounds, we have our choice of magnesite, brucite, dolomite, sea water, brine wells, and even various silicate minerals, including serpentine and olivine. This example is cited merely to show that modern industry is not bound to one source of a given material. Monopolies on ownership of unique mineral deposits are rare, indeed, but where they do seem to exist they can generally be broken by chemical maneuvering. Moreover, man is adaptable; he will change his wants or find substitutes if any article costs too much. In the long run, the international movement of most minerals tends to decline, and the use of elements that are locall abundant and cheap tends to expand.

Competition

A wise philosopher has said that nothing is constant but change. One metal may be substituted for another, and both may gain or lose in the fight for markets with nonmetallic materials. Some metals are light, others heavy; some strong, others weak. For structural purposes, especial in aircraft, lightness combined with strength is demanded. Iron is strong than the same weight of aluminum, but by alloying iron to make steel, it becomes still stronger. Persistent research has turned the tables, howeve and by mating the light metals, aluminum and magnesium, and utilizing a new technique of age hardening, still newer alloys were made that were stronger than ordinary alloy steel. The race goes on in much the same way that the invention of a new armor plate speeds the development of new guns and projectiles, or vice versa. Cadmium rustproofing, after displacing galvanizing, itself had to compete with improved pure zinc plating Interproduct competition between mineral products is keen, but mineral products as a class generally have won over nonmineral products. In the building industry, competition from materials of other than mineral origin has increased only in respect to flooring, wall trim, and perhaps roofing materials. In the broad field of manufacturing, newly developed plastics are being used occasionally instead of metals, but it is significant that none of these synthetic products are processed without mineral raw materia and that some of the newer ones are almost wholly of mineral origin.

An increasing flow of materials from farm and forest may be expected. We hear more and more about chemurgy, the growing of crops for industry. Agriculture has become so efficient that our farmers could produce as much food as they do now with half as many men and half as much land. Already most people in this country are fairly well fed, and the chances for increasing the consumption of food are definitely limited. No such limits are placed upon the consumption of manufactured goods, and if industry will use more farm products our farm problem finally may be solved. It does not follow, however, that the increased use of farm and forest products forebodes competition with minerals. In any event, mineral fertilizers and tools will be needed on the farms, and inorganic chemicals will be needed in the factories and processing plants.

This is an age of specialization, but the student of markets for minerals must scan many fields. Experiments already are under way at the Massachusetts Institute of Technology to capture sunshine and use it for household heating and refrigeration, displacing coal or fuel oil. Only a year ago the hope was revived that soon we might be able to utilize atomic energy. News of splitting uranium atoms came as a surprise even to the physicists, and it still remains to be seen whether the limitless energy sealed in the atoms of terrestrial matter can be released for use as industrial power. To show the implications of atomic energy, however, a Princeton professor, Malcolm C. Henderson, has deduced that by splitting its atoms 8 pounds of uranium would afford enough energy to drive the biggest ocean liner across the Atlantic, substituting for 6,300 tons of oil. The transmutation of elements, the alchemist's dream, is an accomplished fact. Should it prove commercially feasible to fabricate any metal merely by blasting it out of common elements, no metal need ever be called rare. Moreover, spectrographic analysis of rocks and minerals is demonstrating that many so-called rare elements are rare only in the sense that they are less abundant than the more common elements and not localized to the same extent in workable deposits. As more attention is given to recovering these rare elements as byproducts, the variety of elements that jostle one another in search of jobs is increased.

The increasing efficiency of mineral utilization can be illustrated by a specific example. In the Great Wall of China, brass tubes were used to afford means of communication between guard stations. Today, we send 100 telephone messages over a single wire and can even do without the wire. However, these accomplishments, while displacing no one knows how many brass tubes as a vehicle of spoken communication, have created a demand for a variety of other minerals. Not the least of these are the tiny slices of quartz that are needed to unscramble the separate messages. Sand, sandstone, and rock crystal are all varieties of quartz, but the quartz crystals from which these slices are cut are quite different from ordinary sand, which can be had almost anywhere for the cost of digging it. They are a very special kind of quartz, so far found in reasonable quantity only in Brazil, and have the unique property, known as piezoelectricity, that permits them to be used for frequency control in modern radio transmitters and telephone service. They cost $15 a pound, or more, before they are fabricated in any way, and they cost a great deal more after the small slabs are sliced and ground to the requisite nicety.

How Markets Are Found

New uses for minerals do not just grow. They have to be created, and ordinarily it is the producers who must find jobs for their products. The fable of the mousetrap maker to whose door the world beat a path has no parallel in modern business. Research is forever at work to make better products, but the public must be told about the products and shown how to use them. It has been estimated that 215 million dollars a year is spent in the United States for research. How much of the world advertising bill is spent on spreading the news of this research probably cannot be estimated. However, the New York World's Fair, envisioning the World of Tomorrow presented 50 million dollars' worth of exhibits to dramatize the results of corporate research alone.

One of the most frequently cited examples of research applied to market development is nickel. Nickel production soared during the World War, but peacetime uses were few. After 1918, however, the International Nickel Co. expanded its laboratories and proceeded to determine the real uses of its product. Aggressive research demonstrated new and better ways of using the metal, and today automobiles consume 30 to 40 percent of the entire output of nickel, the railroads have become important buyers, and stainless steel and other alloys containing nickel are employed in countles places where no metals had hitherto been considered applicable. Nickel alloys with unusual electrical or magnetic properties have been produced, and the metal is being employed in the chemical industries both to resist corrosion and as a catalyst. In 1930, when depression cut deep into income the International Nickel Co. increased its spending on research by one-thir with the result that 6 years later its sales of nickel nearly doubled those of the best war year.

When platinum metals became an important byproduct of nickel, this company proceeded to find more uses for them, and last year world consumption of platinum metals was around 500,000 ounces, roughly twice as great as in any year before the research was begun. The demand for aluminum likewise has been created largely by the leading producers in this and other countries. The same may be said of markets for magnesium, molybdenum, vanadium, and several other metals.

Research costs the duPonts 7 million dollars a year, but this is only a pittance in the pay-off because almost half the company sales today are of new products developed during the last 12 years. More and more, this company has confined its efforts to products that can be made from half a dozen basic raw materials: Coal, salt, limestone, sulfur, air, and water. The Dow Chemical Co., which spends about $1,500,000 a year on research, has concentrated chiefly on brine from its wells in Michigan, which has become the common raw material for 300 chemical products.

Research on the production and use of new metals and minerals necessarily keeps in close touch with the broad field of technical industrial research and the demands of industry. Some of the uses found for the rarer elements were glimpsed first by research workers employed by the telephone, radio, and electrical companies. Consumers' laboratories, in fact, constantly are seeking the best materials for specified purposes. Occasionally they may hit upon new uses for a material, but as a means of disposing of potential byproducts the process of waiting for consumers to develop new demands unaided, is about as effective as waiting for lightning to start a campfire.

Job Hunters

Many minerals are either wholly or partly unemployed. Rarely, indeed, does the discovery of new uses outrun supplies, and the threat of overproduction has plagued the miner almost as much as it has the farmer. No one is ever fully satisfied with the demand for his product. Potential surpluses, however, do help to gain consumer acceptance for a new product. The beryllium industry, for example, undoubtedly would have grown much faster had prospective consumers been more sure of adequate reserves of ore in the groun

In addition to making market studies of consuming industries and listing names of actual buyers of mineral commodities, the Bureau of Mines watches for what may be termed surplus metals and minerals. Relative abundance in the earth's crust is only one indication of ample supply, for there are other factors, including the tenacity with which some elements cling to their chemical bonds and also the fact that many widely distributed elements are found only in minute percentages in rock masses and not concentrated in high-grade deposits. Many so-called new metals are new only in commercial extraction and utilization, having been known to scientists for scores of years. The term "rare metals" often is a misnomer insofar as it may imply scarcity. Many persons would be surprised to learn that uranium, tungsten, and lithium are more abundant in the earth's crust than is zinc; hafnium and thorium, than lead; and beryllium and rubidium, than tin. Antimony, a relatively cheap metal, ranks low in occurrence. Tellurium, although about as rare as platinum or gold, is a drug on the market at $1.75 a pound, and only recently were uses found for even a small fraction of the tellurium available in metallurgical wastes.

The three most abundant elements in the earth's crust that are stable when isolated from their combinations are, in order, aluminum, iron, and magnesium. The rapid growth in production of the light metals aluminum and magnesium confirms the prophecy that eventually they will rival iron in industrial utility. Silicon, calcium, sodium, and potassium are even more abundant than magnesium, and although none of them except sodium is used so extensively in the metallic state, their compounds have great industrial importance. Rock salt and limestone, in particular, are so widely distributed and so easy to mine that it seems a pity that they are not utilized even more extensively in industry. Enormous quantities of salt water run to waste at oil wells, and inexhaustible supplies of seawater and other natural brine can be tapped at innumerable places. In addition to sodium and chlorine, these brines can be made to yield a great deal of magnesium, calcium chloride, and a host of minor constituents, of which only bromine is now extracted. Hundreds of millions of tons of sea water is pumped annually through the bromine plant at Wilmington, N. C., and if the unrecovered minerals could be extracted profitably, they would be worth hundreds of millions of dollars.

Commercial sources of magnesium or its compounds now include brines, magnesite, dolomite, and brucite and, in Europe, carnallite and kieserite as well. However, as previously stated, other minerals - notably olivine, serpentine, and talc - contain much magnesium, and they, too, may be utilized to a greater extent when the chemists tackle the job in real earnest.

Next to magnesium, titanium is the most abundant metal; it is half again as abundant as carbon. A fair amount of rutile is used for welding rod coatings, and titanium pigments have become important, but we go halfway around the world to British India for our supplies of high-grade ilmenite, and no one seems able to utilize our tremendous deposite of lower-grade material, especially the titaniferous magnetites. Seemingly important uses have been found for zirconium compounds, but those who produce it as a byproduct of rutile would be glad to discover additional markets.

Low-grade manganese and chrome ores are abundant in this country, yet we still class such ores as strategic minerals important enough to stockpile against possible emergency should deliveries from foreign countries be cut off.

The rare-earth metals, oddly enough, are not rare at all. There is doubtless more cerium in the world than there is mercury or antimony, and the probable supply of the group as a whole is greater than that of zinc, lead, or several other fairly common metals. Nevertheless, so far the uses of the rare-earth elements have been confined to sparking flints, and, in the form of compounds, as minor constituents of special glasses. Tellurium is available in much larger quantities than are needed at present Gallium, germanium, and indium are byproducts of the zinc industry that could be recovered in relatively large amounts, but scarcely anyone outside of the laboratory seems to want them. Marked progress has been made in recent years in increasing the demand for chlorine, bromine, fluorine, and phosphorus, but natural supplies of these elements are so abundant that consumption could be increased manyfold without threatening a shortage. Lithium and strontium deposits also are large enough to encourage the search for more uses.

Feldspar is a mineral that has been utilized to a very much greater extent, particularly in the glass industry. Appalling waste, however, occurs in the mines where it is produced, and with perfection of suitable methods of beneficiation, feldspar promises to become much cheaper than ever before. Eventually it may be concentrated out of the waste from granite quarries, and already the ceramic industries are beginning to pay more attention to the utilization of natural silicate rocks. In Canada, nepheline syenites are being mined; last year an aplite mine was opened in Virginia; and the Electrotechnical Laboratory of the Bureau of Mines at Norris, Tenn., is experimenting with alaskite, a naturally occurring rock formation consisting essentially of feldspar and quartz. Other laboratories are working on the utilization of vesicular lavas and various light-color igneous rocks for the manufacture of engobes and enamels of the cheaper sort.

An outstanding need in the ceramic industry is a process whereby small percentages of iron can be eliminated satisfactorily from cheaply minable materials. Ordinary building sand may be worth only 50 cents a ton; a good grade of glass sand suitable for making window glass or automobile windshields, for example, may be worth $2 or $3 a ton; but a glass building-block manufacturer is willing to pay $25 a ton for crushed quartz or sand containing less tha 0.005 percent iron. Much ordinary clay is worth virtually nothing at all, and the clay used in making common brick in most localities could be produced and sold for as little as 50 or 75 cents a ton. Nevertheless, these clays contain virtually the same constituents as high-grade clays worth $7.50 to $30 a ton. Already it is possible to take a $7.50 clay, separate a fraction worth $20 a ton, and still sell the remaining clay at $7.50; but this is a matter of particle-size differentiation and not strictly beneficiation. What is needed most is some means of eliminating minor impurities such as iron, titanium, and traces of vanadium, which stain the product so that it is not white either in the raw state or after it has been fired in a pottery kiln.

The real test of an enterprise is whether it makes full use of its opportunities. Mine dumps, mill tailing ponds, and metallurgical wastes present a perpetual challenge. One by one the minor elements found in smelter smoke and refinery sludge have been caught and put to work. Iron blast-furnace slags are made into cement or mineral wool. In thickly settled communities slag and rock waste are used for concrete aggregate and road construction. Waste slate, however, is not suitable for these purposes, and anything that will reduce the waste or find a market for it would prove a boon to the slate industry. Oliver Bowles, of the Bureau of Mines, helped reduce the waste by introducing the wire saw into slate quarries, and preliminary tests by the Bureau at College Park, Md., indicate that lightweight aggregate can be made from part of the waste; but there is still more to do.

Another old problem is to find wider use for New Jersey greensand, though this becomes more difficult now that our potash needs can be met from other domestic sources. In the South are great deposits of schists that would yield a great deal of kyanite, garnet, graphite, and mica flakes at low cost if only the markets for these products could be expanded sufficiently.

Perhaps the most urgent problem of all is the need to balance demand against potential production of coal. Research on coal utilization covers a broad field, ranging all the way from proposals for burning the coal in the ground (without mining it) to the manufacture of nylon, a synthetic fiber made from coal, air, and water.

Alexander is said to have wept because there were no more worlds to conquer, but the research workers' field of action today is not so limited. Never before has man been so dependent on minerals, and never before were there so many opportunities to find new jobs for minerals. It would be venturesome to preduct which consuming industries afford the best opportunities, but apparently the minerals that will be the most successful in finding new jobs in the future, even more than in the recent past, will be those that are abundant in nature and so can be produced at low cost.